4 DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN
XV to XVIII Centuries

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Survey and Deterioration Analysis for the Restoration of Fortified Architecture: Case Study of the Malta Walls.

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Abstract

This paper describes the survey technique and decay analysis applied during a recent study funded by the Maltese government, to support the restoration design of the Malta walls. The surveyed walls refer to Valletta and Birgu and have a total length of 2 Km, for a total surface of 35000 m^2. As a conclusion of these large scale survey and analysis, it is possible to highlight the complex environmental and architectural context that influences the deterioration of the Maltese walls and propose a sustainable direction for restoration works. Starting from the study results, the paper aims to focus the importance of the relationship existing between deterioration survey and architectural analysis within conservation process; highlighting the limit of the widespread practice of considering the possibility of a direct correspondence between degradation phenomena and restoration work.

Keywords: fortified architecture, deterioration survey, conservation process, prevention.

1. Introduction

Many architectural and historical studies as well as scientific investigations have examined degradation of Malta defensive walls from a geological, chemical and physical point of view but very few works have linked research on diagnosis with a more general consideration of the building state of conservation and its conservative needs.

The uniqueness of each event of deterioration should be considered with respect to the architecture and the environmental conditions where it arouses. Moreover, its effect may change according to the different conditions, the phenomenon itself may not be completely detrimental to the object and its complete removal might result in even greater harm.

An integrated survey focused on understanding the complex interaction between architectural configuration and degradation survey appears to be an important instrument to enhance historical building protection. As a matter of fact, the deep knowledge of the monument context leads to highlight an operational practice oriented preferably towards prevention than necessarily destructive intervention [Jedrzejewska 1976].

1.1. Historical and Geographical context of Malta

The walls of Malta were built mainly in 1563 after the Turkish siege, by the Knights Hospitaller. Extensive renovation and reconstruction works gradually changed the features but the layout is generally defined from the origin [Huges 1969]. Malta is an island of the East Mediterranean basin and lie at a latitude between 34 and 36 degrees north. The main winds that blow on Malta come mostly from the North-West. The building stone used is a soft limestone, called Globigerina, belonging to the large family of Oligo-Miocenes. It is commonly found in the Mediterranean Sea and its carving and shaping are very easy. This globigerina limestone contains numerous shells, algae and planktonic fossils, above all planktonic foraminifera Globigerina [Pedley et al 2002]. Local stone workers may macroscopically be distinguished in two building stone qualities: 'Franka' and 'Soll'. While 'Soll' is a bad quality building material, 'Franka' better resists environmental conditions. The difference may be seen in abandoned quarries where the stone shows different degrees of weathering [Rothert et al 2007, 191] as well as in the benches on which the walls are built.

Like all the ramparts of the town, the wall sections analysed in Valletta (fig. 1) were built by shaping the natural bench of soft local limestone. The summit and other strategic areas, both constructively and defensively, were realized with rows of square blocks made of the same material. The walls were built following the specific morphology and altitude profile of each site, with heights varying between 10 and 30 m. The height of the stone blocks varies between 30 and 45 cm and the width between 70 and 100 cm. The different sides of the walls have different heights, constitution and assets.

The external front, with an average height of 25 m, is characterized by the predominance of stone bench work, marked by discontinuous human intervention and flanked by few green areas and driveways.

The inner side, typically 1-2 m high, consists of regular rows of blocks and follows the sidewalks and streets of the Old Town. The very thick wall has a large parapet of varying geometry, set with square blocks and sometimes protected by occasional drafts of mortar.

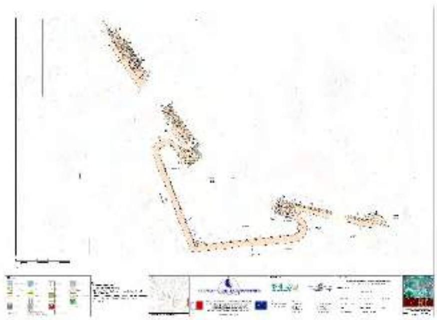

Fig.1- General plan of Valletta survey.

The sections of walls analysed in the 'Post of Castille' in Birgu (fig. 2) were built, as in the case of Valletta, mainly by laying horizontal rows of square blocks of the same stone. In some places the wall is directly on the limestone bench. The entire outer face of the section analysed is typically built with a scarp wall profile culminating in a rectilinear section interposed with battlements. These are in most cases preceded by a moulded cornice which consists of a 'cyma-strip-taurus' sequence.

The vertical outer walls height varies between 16 and 18 meters, while the dimensions of the interior walls depend on the space delimited. The ground plan of the fortress is fairly compact but is divided internally mainly into three sections defined by four wall fronts, facing outwards toward the west and inwards toward east. The external end defines the two ramparts and the internal sighting areas, at a lower height of about 8 meters, are the parade ground whom access consists of a rich portal preceded by a two-ramp stairs. The structures are internally intersected by tunnels that open into different rooms.

2. Study Case of Malta[1]

2.1. Formal-Geometric Survey of Fortified Structures

The problem of survey and representation in the restoration and conservation of fortified structures may have different connotations, if considered above all an investigation tool, a support for the organisation of different types of information and knowledge on the of the architectural structure.

Fig. 2- Birgu, Malta. Aerial photograph of 'Post de Castille' (Laura Baratin 2011).

Thanks to the contribution of other fields, the knowledge available may range from geometric documents of the objects in question, an accurate qualitative description of the materials and their physical-chemical consistency, the state of deterioration and conservation, an analysis of the context and the environmental conditions of the structure.

When talking of surveys involving castles, fortresses and fortified systems, the first reference in ancient tradition dates to the Renaissance, which was the most fertile era not only for the production of drawings but also for the definition of measuring systems. An authoritative point of reference for scholars and technicians of civil and military architecture is undoubtedly Francesco di Giorgio Martini, who, among other works, wrote – *The Treatises of Engineering Architecture and Military Art* – and provided important clarifying contributions in various fields.
In particular, in his *Treatises* he on one hand underlines the importance of the localisation of these works and, on the other hand, in terms of their graphic documentation, he attempts to explain the main elements through which architectural representation is expressed.

Maps are undoubtedly the most immediate and valuable documents for these monumental complexes and according to requirements, may provide more detailed metric information not only of the planimetric and altimetric descriptions of the structures represented but may also be used to define the correct volumes of the adjacent spaces.

Numeric maps and 3D surveys today play a completely new and original role since, with the representation of different points by means of the corresponding three space coordinates, they open new possibilities in terms of monument data management and documents.

Taking architectural survey to the precision of cartography means going back to the logics of measuring, which is based on tools and procedures that permit defining from time to time the range of reliability of the measuring system used and to test results. From this point of view, architectural survey becomes an information tool consisting of metric data organised as graphic or numeric models [Baratin 2006, 115-119].

For the surveys of a part of the Valletta and Birgu fortifications in Malta, which have very complex structures, various techniques were used in order to obtain "maps to support" all the information required for the successive analysis of the state of conservation as well as 2D and 3D documents. The investigation was developed gradually, from a first general representation to the more detailed representations necessary to organise all the data subdivided stone by stone, structural element by structural element.

The survey, which included various techniques, consisted of the following phases: 1. a topographic survey to obtain a geometric framework of the structure and a reference grid for the other methods used: photogrammetric surveys, laser scanning, longimetric and photographic surveys and so on. In this phase, the level of accuracy, which may be verified by successive compensation of the data acquired, is established. The survey is carried out in this phase by connecting to the National Geographic coordinate system by means of two fixed Trig Points. This makes it possible to georeference the finding and add it, even at a later stage, to existing cartographic data as update to the map.

High precision networks are then measured, starting with the framework network, in order to connect all the detailed areas and the successive survey operations carried out with other systems (fig. 3).

Fig. 3- Birgu, Malta. Scheme of topographic network.

Fig. 4- Birgu, Malta. Scheme position of laser scanner.

2. laser scanning to collect 3D data of all the architectural elements of the fortified system (fig. 4).

The scans are used to produce, by means of a point cloud, an exact copy of the object in question, from which traditional representations may be obtained such as plans, views and cross-sections, according to the plans defined; or a model whose geometric-formal and material consistency may be explored interactively (fig. 5).

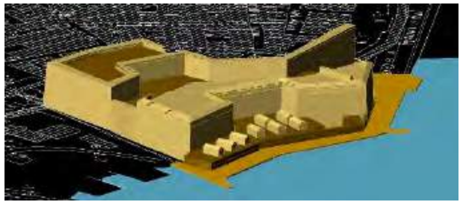

Fig. 5- Birgu, Malta. 3D Model of the area.

3. digital photographic survey to map the surfaces and/or for photographic rectification by means of metric digital and/or non-professional equipment.

The photographic survey is used to document the different objects, for mosaics and rectifying the facades, by means of specific software and measuring the topographic support points identified with artificial markers and/or natural points and finally to map the cloud point obtained from the laser scans. The images are defined during the survey phase to cover the entire area investigated, at a scale suitable for the detail level required.

Once the data had been acquired they were processed to construct the final products through the following steps:

- compensation of the framework networks, connection of networks to the existing national network, calculation of all the points for the detailed and supporting survey required for the more strictly topographic phase;

- recording of the cloud points obtained by laser scanning, georeferencing of the cloud points and definition of the different survey phases into a single reference system, final verification of data and quality control of data according to the required accuracy level, analysis of the laser cloud points, through filtering and processing, scanning and orientation, subdivision into "islands" to facilitate data manipulation, accentuation and/or reduction of triangles for areas with complex geometries, transformation of the triangulated surface into complex surfaces (mesh), control of the model through a topographic survey again according to the level of detail and accuracy of the survey with respect to the part related to laser technology.

The products obtained were plans, cross-sections and views in different scales, from scale 1:200 to scale 1:100 and 1:50 in order to have sufficient information on a stone by stone basis. The complete documents of the topographic and laser scanning surveys together with results and accuracy levels, the photographic documents of each phase of the investigation, the monographs and description of each station summits and topographic detail point are attached to these documents.

Data formats are as follows: DXF for the graphic representations, ASCII for data and TIFF for images. All the data relevant to plans, cross-sections and views was also produced in a format that may be transferred to the existing GIS of the Malta administrations.

2.2 Decay Survey

2.2.1 Method

An initial overall investigation made it possible to inspect the parts of the walls analysed in order to verify accessibility and visibility and develop the most appropriate survey system based on analysis conditions and restitution requirements. In the meantime, the main types of degradation were identified to develop a sampling to be subsequently verified. The patterns identified were generally defined referring to the international [ICOMOS-ISCS 2008] illustrated glossary. The work was set up on a system for the progressive acquisition and verification of data gathered with:

- direct on-site inspections;

- realization of continuous photographic mappings of surfaces;

- reading and interpretation of direct measurements and photographs;

- drawing of results;

- on-site verification of results (this operation must be carried out at different times during the day because of the high natural lighting of the site and the natural reflection tendency of limestone);

- final drawing (fig. 6) of the processed data integrated with eventual corrections using as the basis of the drawing, 2D relief 2D taken to scale 1:200 (summary drawings) and 1:100 (separate components that specifically illustrate the trend of degradation).

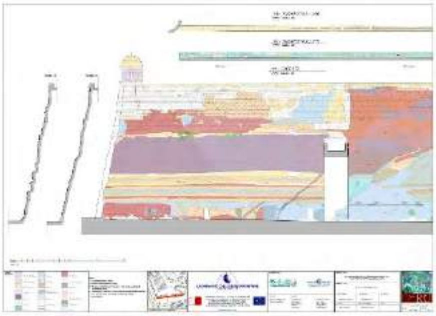

Fig. 6- Valletta, Malta. Decay survey of southward side of Saint James Bastion.

2.2.2 Interpreting the deterioration patterns

The pathologies detected, consist of several phenomena, physical, chemical and biological. [Cassar 2002, 33-50]. Decay phenomenon, as is known, are induced by endogenous and exogenous factors. The first depend on the building material characteristics, the latter on the environmental context. In particular, the maltese walls show that deterioration is also deeply linked to architectural conformation and exposure, showing a substantial differentiation of behaviour between the bench rock and the built up areas. On the bench rock the geological stratification determines the concentration of degradation in the 'softest' layers, favouring the creation of large continuous deeply weathered bands in the limestone bank (fig. 7). Masonry deterioration appears less aggressive because of two reasons principally: the better quality of the ashlar stone, carved from the quarry, and the common practice of replacing masonry developed in the last century. In addition, another frequent pattern regards the numerous cracks of the stone bench, related to geological settling. Alveolar weathering, scaling and flaking may be interpreted as gradual degradation that culminates in powdering and deep weathering of the stone [Cassar 2002].

As an example of deterioration development we present the description of the survey carried on St. James Bastion area. The western side of the St James Bastion shows an alternation of back weathering, biological patina, powdering and alveolar weathering.

Fig. 7- Valletta, Malta. Rock bench and masonry degradation (Marta Acierno 2011).

Numerous deep man-made horizontal, vertical and oblique cracks run through the lower area of the counter, the masonry in the upper section part is affected by weathering and powdering, while biological patina is above all limited to the top and far north sections. There are also numerous brick and limestone fillings on the bench and concrete fillings and patching on the stone curtain.

The southern side of St James Bastion (fig. 6) is characterised by stratified degradation which appears in layers in the west area in the lower part of the bench (powdering, alveolar weathering, back weathering, biological patina), as well as significant erosion and powdering in the intermediate area of the front (formed in part by the bench itself and in part by masonry). The top of the curtain was consistently reintegrated with concrete, presumably because this section was extremely eroded at the time. The east side of the southern front is mostly affected by weathering similar to that on lower section and powdering of the curtain, with widespread biological patina near the rampart. It is worth mentioning that the damage is caused by the presence of vegetation, whose roots dig into the cracks on the bench, making it easier to break.

2.2.3 Critical Discussion

The walls of Malta are mainly affected by two types of degradation, characterised by substantially the same biological (biological settlement) and physical phenomena.

Biological aggression appears mainly on the north-facing sides where there is major humidity. The effects on the building show either a black patina or secondary vegetation. The actions it triggers are both physical and chemical, the first consists of root penetration, while the second consists of the process it generates, inside the stone, to obtain nourishment.

One of the most important aspects to consider during the survey is the correct diagnosis of biological aggression. This can in fact significantly affect the efficiency of the intervention. Some species such as lichens may harmlessly coexist on the stone surface and even moss, if properly monitored, will not harm the surface[2]. The current practice in Malta however consists in their total removing which not only means losing 'that half-inch of authentic surface' but also makes materials more vulnerable, and often leads to deep weathering, namely loss of material. The issue is, therefore, whether it is worse to protect an authentic area whose look has been altered by the presence of a patina that reflects the passage of time or releasing it from the aging process with the risk of losing it irreversibly. Physical damage is manifested by different levels of progression[3]. As Jean Cassar (Cassar2002) has pointed out the degradation process of globigerina developes into different phases. Initially the formation of a thick crust (1-2- cm), due to re-precipitation of calcite, is observed.

This material is actually dissolved by the water present in the stone. As the solution and re-precipitation phenomenon follows cyclic processes, several layers of crust are generated on the stone surface. These layers are actually very vulnerable.

Thermal stress and crystallization of the salts induce tensions, within the layers, such as to cause them to fall, leaving exposed the inner surface of the stone. This surface shows loss of cohesion, erosion and powdering, as well as greater porosity which results in further accumulation of salts. On the maltese walls the effects are usually 'exfoliation' and alveolar weathering that develop into gradual scaling and deep weathering. Particularly, exfoliation is influenced by the globigerina petrografical composition (as it has also been explained) and by wind-induced stress; it is in fact particularly evident on the North-West walls, which is the direction of prevailing winds in Malta.

Another esogenous factor is thermal oscillation that produces a continuous alternation of expansion and contraction, and occurs above all in sunny areas which are more exposed to temperature fluctuations (fig. 8).

Fig. 8- Birgu, Malta. Scaling and back weathering on southern fronts (M.Acierno 2011).

Alveolar weathering is mainly due to the crystallization of salts. In those places which are more exposed to sunshine or air movements on the stone surface, the rate of water evaporation in the masonry is greater, and the phenomenon is amplified. The most affected areas are, therefore, the southern fronts and those with better ventilation in the north-west. Alveolar weathering is also particularly evident on the interior of the walls where the phenomenon is emphasized by dampness caused by rainwater pooling at the foot of the structure (fig.9).

Fig. 9- Valletta, Malta. Alveolar weathering on the parapets facing the town (M. Acierno 2011).

Beyond traditionally considered endogenous factors, such as climate conditions, another interesting aspect that influences the manifestation of degradation ascertained on the walls studied, is the impact of the architectural features on the causes of degradation. As is known, protected and less washed out areas are those most exposed to chemical aggression, but the survey conducted in Malta clearly demonstrated that the stone work and more generally architectural configurations are strongly linked to degradation. Protruding surfaces that are more exposed to air movements show major alveolar weathering so that all the curved volumes, regardless of size, like those of the ramparts or mouldings are heavily honeycombed.

Considering buildings such as the Maltese fortifications where the only decoration is the crowning corniche in *torus* or *cyma*, damage may greatly affect the overall design, compromising its architectural 'identity'. Considering the impact on the definition of the features, it is important for the survey on degradation to take this into account. It is therefore important to recognize when back weathering leads to the formation of lacuna, i.e an 'interruption of the feature pattern'.

Correct identification of the decay phenomenon necessarily includes an assessment of both damage to the materials and the image of the monument. Back weathering may lead to consolidation or protection works, but may also result in reintegration that should take into account the overall architectural image.

3. Conclusions

The causes of deterioration of the defensive walls of Malta are mainly related to climate conditions, whose impact is itself cyclical and quite predictable. A general conservation strategy should aim at prevention attempting to mitigate the effects of decay phenomena controlling the environmental conditions.

The intervention may not be conceived as a two-way response to degradation, as tenders often require, but should relate to whole the complex system of relationship that the building establishes with its physical and cultural context during its life. The deterioration survey that necessarily precedes the project should in any case necessarily include an assessment that takes into account how the monument has been handed down to our times and how restoration will be part of this process ensuring as far as possible care, harmony and continuity.

Notes

[1] The work has been financed by European funds, and was the object of an international tender called by Malta Restoration Unit. The authors were part of the winning group; this was organized into two work units. One focused on topographical and geometrical survey, directed by Laura Baratin the other, addressed on decay investigation, directed by Donatella Fiorani. In the paper the section concerning survey was written by Laura Baratin while the parts on decay analysis by Marta Acierno.

[2] Although no laboratory analyses were carried out (because these were not provided by Tender), these are considered to be necessary in the future, above all to better understand the nature of biological patina and black crust and the composition of the mortar employed for the joints.

[3] An interesting study on globigerina decay was carried on by [Rothert et al 2007].

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